The wicked problem of suspended sediment profiles: a choice criterion

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PROBLEM DESCRIPTION

The study of suspended sediments in rivers is of very high importance for water quality management and it remains one of the most challenging subjects in hydraulic and environmental fields. Such a study requires a good understanding of the vertical distribution and velocity of suspended sediments.

More than one concentration profile can be found in the literature, and it is well known that they are highly sensitive to the parameters used to calculate them. Our present challenge is to make the optimal choice of concentration profile for given hydraulic hypotheses. This is not straight-forward because of the underlying problem of the applicability of a profile built under given constraints on more general situations.

TOOLS

In order to enhance the study of suspended sediments in rivers, we investigate the key parameters controlling the classical vertical suspended sediment profiles obtained for rivers in steady and uniform conditions. The profiles obtained from diffusion models are compared based on:

– Flow properties: turbulence and mean flow velocity.
– A sediment property: mean sediment concentration.

The effect of other sediment parameters (e.g. the size, the shape and the nature of sediment) and topographic parameters of the transporting body (e.g. the shape and dimensions of the channel) are not considered here, in order to focus on the decisive effect of the above-mentioned parameters on the choice of a suspended sediment profile.

We study the suspension over a flat bed (absence of bed forms) and we take the reference elevation as the height of the bed load layer referring to Van Rijn (1984).

KEY LESSONS

Influence of basic parameters on the suspended sediment profiles

We follow the calculations of suspended sediment profiles in detail to see where each parameter is used and, consequently, how it can affect those profiles Van Rijn (1984). Table 1 summarizes the results.

Choice of a concentration profile

The choice of a concentration profile in the present work is based on the mean sediment concentration, the mean flow velocity and on the damping effects of sediments on turbulence. Based on those parameters, we suggest the following criteria for the choice:

(a) For low concentrations (less than 10 kg/m^3). According to Van Rijn (1995), the classical profile based on a parabolic constant mixing coefficient assumption is the one in best agreement with experiments.

Table 1 Parameters influencing the suspended sediments profiles.

Field		Profile affected through	Field		Profile affected through
Sediment	Nature	– Dimensionless particle size parameter – Representative diameter of suspended sediments – Particle mobility parameter – Critical bed shear velocity – Dimensionless bed shear parameter – Ratio of sediment to fluid mixing coefficients – Particle fall velocity – Suspension number – Reference elevation – Reference concentration	Flow	Damping	– Mixing coefficient
				Water depth	– Critical bed shear velocity – Ratio of sediment to fluid mixing coefficients – Suspension number
				Mean velocity	– Bed shear velocity related to grain – Dimensionless bed shear parameter – Reference concentration
Channel	Size	– Same parameters as before	Reference data	Elevation	– Integration initial value
	Concentration	– Fall velocity – Correction factors			
	Slope	– Critical bed shear velocity		Concen tration	– Integration initial value – Correction factor
	Viscosity	– Same parameters as sediment nature			

(b) For high concentration (volumetric concentration greater than 20%; Van Rijn, 1995). The settling velocity will be affected by this concentration and will be given in this case by the Richardson Zaki type, according to Van Rijn (1984). The convection–diffusion equation cannot be solved analytically and we distinguish three cases:

(i) When the coupling effects (effects of sediments on turbulence) are being neglected, the concentration is given by an analytical equation cited by Van Rijn (1984) and that must be solved numerically.

(ii) When the damping effects are considered of significant influence, the sediment mixing coefficient must be modified by the introduction of a multiplicative scalar to account for the damping effects. The convection–diffusion equation is solved numerically using the Runge-Kutta method with an automatic step reduction.

(iii) For high velocities (1–3 m/s). A simplification given by Van Rijn (1984) consists of modifying the Rouse number by the mean of an additive parameter that is a function of the settling velocity, the critical bed shear stress and the reference concentration. The obtained formula was tested by Voogt *et al.* (1991) and it shows the best agreement with experiments in this case.

OUTLOOK

The choice of a concentration profile in the case of median load is not treated clearly in the literature and the quantification of the criterion “low concentration, high concentration” differs from one reference to another (e.g. hyper-concentration for Van Rijn, 1995, is in the range of 20–60% and for Julien, 2002, in the range 5–60%). This shows the complexity of the problem and opens new windows for upcoming research.

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